BT-2598 Hydrogen for Military Purposes

BT-2599 German Documents on "Notes of the Balloonist"

BT-2600 Regarding Leakage of Hydrogen from Balloons

BT-2601 The Lift of Hydrogen

BT-2602 Electrification of Observation Balloons

Air Service, Washington, D.C.

1920-1921

BT-2598

Hydrogen for Military Purposes

Air Service, Washington, D.C.

20 Aug 1920

AIR SERVICE INFORMATION CIRCULAR

(LIGHTER-THAN-AIR)

PUBLISHED BY THE CHIEF OF AIR SERVICE, WASHINGTON, D. C.

Vol. II | August 20, 1920 | No. 157

HYDROGEN FOR MILITARY PURPOSES

WASHINGTON
GOVERNMENT PRINTING OFFICE
1920

HYDROGEN FOR MILITARY PURPOSES.

The production of hydrogen for commercial purposes has naturally been toward the development of methods which insure low cost and the equipment designed is usually for permanent installations. Greatest efficiency in the production of hydrogen for military service involves processes which permit of easily transportable generating equipment, ample available supplies of chemical substances and purity of gas. It is often practicable for the Army to use hydrogen plants of commercial types, shipping the gas compressed in cylinders, so that it is important that officers assigned to the lighter-than-air service become familiar with all practicable methods.

PROPERTIES OF HYDROGEN.

Hydrogen is a colorless and odorless gas when pure. Frequently in the manufacture of hydrogen by chemical processes impurities in materials cause combinations of sulphur, carbon, and arsenic, which with hydrogen even in minute quantities, produces an odor often incorrectly referred to as that of hydrogen.

Hydrogen is the lightest known gas, having a specific gravity of 0.0696, referred to air at same temperature and pressure, which is equivalent to a weight of 0.005621 pounds per cubic foot at temperature of 0° C. and 76 centimeters (0.001476 grams per cubic centimeter, at 0° C. 76 centimeters). One gram (15.43 grains) at 0° C. 76 centimeters equals 11.11 liters equivalent to 678 cubic inches of hydrogen. One grain of hydrogen at 60° F. and 30 inches barometric pressure equals 46.45 cubic inches.

Compared with other gases, hydrogen is absorbed very slightly in water. At 0° C., the absorption in water is 0.00192 and at 80° C., the absorption is 0.00079 referring to weight in grams H_2 absorbed in 1,000 grams of water. Hydrogen becomes liquid at a temperature of minus 220° C. when subjected to a pressure of 20 atmospheres. No matter how low the temperature, the pressure must be at least 14 atmospheres, and, at this critical pressure, hydrogen liquefies at minus 240.8° C.

The coefficient of expansion of hydrogen due to temperature changes is 0.00366 per degree centigrade at a pressure of 100 centimeters of mercury, and between the temperature of 1° and 100° centigrade. This coefficient of expansion should be particularly noted for the reason that in less than 24 hours, changes in temperature of 72° F. (40° C.) in the North Temperate Zone are not unusual. A lowering of the temperature 40° C. reduces the volume of gas nearly 15 per cent, causing a kite balloon of 25,000 cubic feet capacity to become flabby and have the appearance of losing 3,200 cubic feet of gas.

Boyle's law states that for a constant temperature the volume of gas diminishes in direct proportion to the pressure, but this applies only to ideal gases, of which there are none. The divergence of actual gases from Boyle's law does not follow any formula; a curve plotted for any one gas is irregular at various pressures. (See Smithsonian Physical Tables.) Hydrogen is less compressible than indicated by Boyle's law, while nearly all other gases are more compressible. At normal temperatures and a pressure of 2,000 pounds per square inch (136 atmospheres), the quantity of free hydrogen in commercial cylinders of 2,640 cubic inches should be, according to Boyle's law, 208 cubic feet, whereas experiments show only 191 cubic feet. (Bureau of Standards.)

Hydrogen will burn in air when the percentage is as low as 4½, the flame traveling upward when ignited below. As the percentage of H_2 increases to 9, the flame will travel downward or in any direction. Further increases in percentage H_2 increases the intensity of the flame propagation, which when very rapid and violent is called an explosion. The flame propagation is increased when the hydrogen is mixed with oxygen not diluted with nitrogen as in air. Examples of this power and effect are occasionally observed when hydrogen and oxygen are accidentally compressed in the same cylinder.

VITRIOL PROCESS.

One of the oldest and best known methods for hydrogen production is the vitriol process. The action of sulphuric acid on iron or zinc evolves hydrogen as shown by the following chemical equation:

$$Fe+H_2SO_4.\ Aq=FeSO_4+2H.$$

It is essential that dilute acid be used for the reason that concentrated sulphuric acid forms a film of sulphate of iron on the surface, which is soluble in water but not dissolved by the concentrated acid. This process is so well known that a detailed description here seems unnecessary. The generating equipment can often be improvised by using substantial barrels or vats of wood or large glass or earthenware carboys, and lead pipes for conducting the acid. The caution to always pour the acid into the water and never the water into concentrated acid can not be repeated too often. Furthermore, when using improvised equipment or even specially constructed generators that are not positively gas tight, never strike a match or carry an open light such as a lantern near the generators.

It is found in practice that the washing and purifying of the gas by the usual methods does not entirely remove the water vapor carrying traces of sulphuric acid, which is most injurious to rubberized balloon fabrics; for this reason the vitriol process is not favored when it is practicable to secure hydrogen by other processes, but if it must be used then special precautions should be taken such as multiplying the number of washers and purifiers and

frequently changing the lime in the purifiers. Fresh unslacked lime is used in the purifier to absorb the moisture charged with traces of sulphuric acid which passes out of the hot generating tanks. The lime (CaO) has a great affinity for water ($CaO+H_2O=Ca\ (OH)_2$) changing it to slacked lime (calcium hydroxide) upon absorbing the water. The lime also combines chemically with the sulphuric acid forming calcium sulphate ($2CaO+H_2SO_4 = CaSO_4+Ca\ (OH)_2$). Greater purity of hydrogen can be insured when the weight of apparatus is unimportant, as in permanent installations, by adding in series more purifiers containing chemical substances such as caustic soda ($NaOH$) and calcium chloride ($CaCl_2$) both of which have property of absorbing moisture which is carried along with the hydrogen.

In order to determine the quantities of chemicals required to produce a certain quantity of hydrogen by any process, apply the atomic weights of the elements in the chemical equations in the manner shown below: for example, making the object of the computation 1,000 cubic feet of hydrogen, it is necessary to determine first the number of cubic feet of hydrogen in 1 pound of the gas. This is found to be about 178 feet by taking 12.388 cubic feet of air as weighing 1 pound and considering air as 14.4 times heavier than hydrogen, which figures are sufficiently accurate for this purpose.

Example: $Fe + H_2SO_4 = FeSO_4 + H_2$ $55.84 + (2 + 32 + 64) = 152 + 2$

Then by proportion

$$356 \text{ cu. ft. H} : 1000 \text{ cu. ft.} :: 55.84 \text{ lbs. Fe} : X$$
$$X = 157 \text{ lbs. iron.}$$

Similarly for sulphuric acid

$$356 : 1000 :: 98 : X$$
$$X = 275 \text{ lbs.}$$

It is seen from the foregoing that 157 pounds of iron and 275 pounds of sulphuric acid are theoretically required to produce 1,000 cubic feet hydrogen, but in estimating or purchasing these materials it is always advisable to increase the amounts by at least 5 and better 10 per cent to allow for impurities in chemicals, incomplete chemical action, and losses of gas due to generators and pipes not being gas-tight in improvised apparatus.

The atomic weight of zinc is 65 and by a similar chemical equation it is found that theoretically 182.5 pounds of zinc and 275 pounds of sulphuric acid are required to produce 1,000 cubic feet of hydrogen.

$$Zn + H_2SO_4 \,.\, Aq = ZnSO_4 \,.\, Aq + 2H. \quad 65 + (2 + 32 + 64) = 161 + 2$$

At least 5 per cent should be estimated above the theoretical amounts, for supplies of zinc and acid. Zinc usually contains some lead as impurity; the lead is not objectionable, but on the contrary is said to assist in promoting rapid chemical combination due to galvanic action.

Using only the quantities of iron and acid according to the theoretical computation and assuming the cost of iron turnings at 2 cents per pound and acid at 3 cents per pound, the cost of materials alone to produce 1,000 cubic feet hydrogen would be $11.39.

ELECTROLYTIC METHOD.

Hydrogen of greatest purity is obtained in commercial practice by the electrolysis of water, the hydrogen collecting on the negative electrode and the oxygen on the positive eletrode where current enters the cell. A *direct current* of electricity is passed through water in a suitable cell which is provided with pipes for collecting both gases. The electro-chemical equivalent of hydrogen is 0.0000104 grams per coulomb which in larger units amounts to nearly 15 cubic feet of hydrogen for a current of 1,000 ampere hours. The theoretical electromotive force required to dissociate water into its constituent elements is 1.47 volts between electrodes. Therefore, due to the internal resistance of the cell, if the voltage required is 2, then the computation shows that 1 kilowatt hour of electric power will produce 7½ cubic feet of hydrogen.

The internal resistance of cells increases with the distance between the electrodes, and decreases as the size of the eletrode increases. It varies also depending upon the nature and specific gravity of the electrolyte in the cell.

Pure distilled water is a very poor conductor of electricity and extremely high e. m. f. would be necessary unless the conductivity is improved by adding suitable chemicals to the water. Ordinarily, pure caustic soda ($NaOH$) is used, bringing the solution to specific gravity between 1.2 and 1.25 at 60° F. It is found experimentally that 2¼ pounds of chemically pure caustic soda are required to bring 1 gallon of distilled water to 1.25 specific gravity. This is about 17 per cent caustic soda and is the point at which the solution has the greatest conductivity. Adding more caustic soda increases the internal resistance. Caustic potash (KOH) may also be used for electrolyte but larger quantity is required and the present cost is much greater than that of caustic soda.

There are two general types of construction for electrolyzers, one being the unit type which consists of separate cells, each containing the positive and negative electrodes, connected electrically in series; the other general type being called by various names, "bi-polar," "multiple-plate," and "filter-press" types. These electrolyzers are usually constructed by assembling large plates very close together separating the positive and negative electrodes by sheets of asbestos; where 110 volt power is available these generators have 60 pairs of plates. The advantage of the multiple plate type over the unit cell type is principally lower first cost and less floor space required. The disadvantages being in greater maintenance cost and difficulty of preventing leakage of gas. Most of the electrolyzers made in the United States, both unit type and bi-polar, utilize a special weave of asbestos cloth as separator for the hydrogen and oxygen within the cell. The foreign-made cells at Fort Omaha have a very fine wire gauze to separate the gases.

The quantity of hydrogen produced by this method is proportional to the amperage passed through the cell. For the American made electrolyzers the current varies from 35 amperes to 1,000 amperes, and for the Siemens cells at Fort Omaha the normal current is 1,500 amperes. The e. m. f. required for each unit cell or for one pair of plates in the multiple type will average 2 volts, but de-

pends entirely upon the internal resistance of the cell, which in turn depends upon the size of the electrodes, distance between them, nature and specific gravity of the electrolyte and the temperature. It is observed in practice that in starting the plant when cells are cold the e. m. f. per cell is often more than $3\frac{1}{2}$ volts, which reduces to less than 2 volts after the cells become hot.

As the water in the cells is converted into gas, it must be replaced by pure distilled water. The quantity being 5.76 gallons for 1,000 cubic feet of hydrogen. It is seldom necessary to add caustic soda to the solution and then only enough to replace the very small quantity which is carried off from the cells by the moisture with the hot gases, but even this vapor may be condensed and recovered to some extent by moisture traps of various kinds.

Most manufacturers of electrolyzers in the United States claim an output of $7\frac{1}{2}$ cubic feet of hydrogen per kilowatt hour. As shown in the preceding paragraphs, this means an e. m. f. of not to exceed 2 volts per cell. When it is possible to secure electric power at 1 cent per kw. h. the cost of 1,000 cubic feet of hydrogen for power alone is \$1.57 (assuming motor-generator efficiency of 85 per cent, and electrolyzer efficiency of $7\frac{1}{2}$ cubic feet hydrogen per kw. h.)

The electrolytic plant installed by the Army at Fort Omaha in 1908 consists of 30 large cells made by Siemens Bros. Co. (Ltd.), London, the normal current being 1,500 amperes and the voltage varying from 4 to 2.2 per cell, depending on temperature. The temperature should be maintained at 150° F. Higher than this is likely to damage the insulation and produce an excess of moisture with the gas. Lower temperature increases the internal resistance and cost of electric power. Each cell produces 23.3 cubic feet of hydrogen per hour, a total of 699 cubic feet per hour for the 30 cells, equivalent to 16,776 cubic feet per day of 24 hours for the plant.

SILICOL PROCESS.

The production of hydrogen by dropping ferrosilicon into hot caustic soda is, in the French and British armies, known as the "silicol" method; in Germany it is called the Schuckert process, and for many years the details of it were carefully concealed.

The chemical reaction producing hydrogen is between silicon and caustic soda without any change in the iron. The following chemical equation will serve to explain the process: $Si+2NaOH+2H_2O=Na_2SiO_3+4H+H_2O$. In Germany it was customary to use pure or nearly pure silicon. In France this method was developed for the military service by Capt. LeLarge and Dr. Jaubert, their generating apparatus being designed in three types, viz: Autotruck transportable size, semifixed, and for permanent installations. Ferrosilicon is used, being more easily secured and at less cost than pure silicon as in the Schuckert generators. The steel industry in this country uses large quantities of ferrosilicon containing 50 to 75 per cent silicon. Experiments have shown that more satisfactory chemical action is secured by having the silicon content 80 to 85 per cent. Commercial caustic soda of 97 per cent NaOH is suitable.

Except in very cold weather the mixing of caustic soda with water produces sufficient heat to start the chemical combination of silicon and soda. It is necessary to agitate the solution constantly to secure best results and avoid sudden generation of large quantities of gas of explosive violence. The solution resulting from the chemical combination is sodium silicate, which may be easily drawn off at the bottom of the mixing tank.

According to the chemical equation, the production of 1,000 cubic feet of hydrogen would require 39.6 pounds of pure silicon and 112.3 pounds of pure caustic soda. The actual quantities which should be supplied depend upon the silicon content of the ferrosilicon and the percentage of purity of the caustic soda. An experiment conducted for the army determined that 58 pounds of 80 per cent ferrosilicon and $125\frac{1}{2}$ pounds caustic soda would produce 1,000 cubic feet hydrogen. Ferrosilicon at 15 cents per pound and caustic soda at 3 cents per pound would bring the total cost for materials to \$12.46 per 1,000 cubic feet.

Ferrosilicon may be stored without deterioration by moisture and without any special precaution for its care. The caustic soda must be protected from moisture and is usually supplied in air-tight drums containing 100 pounds.

In connection with silicol generators there are required washers and purifiers to remove from the gas the hot vapors carrying caustic-soda solution. Field generators of this process should always be set up for operation near a stream or other ample supply of water. It is possible to design the generating equipment with radiators for cooling the circulating water for situations where water economy is important.

IRON CONTACT PROCESS.

The iron contact process for production of hydrogen is often referred to as the regenerative steam and iron method, the principle being that when steam passes over red-hot iron it is decomposed into its constituent elements, the iron absorbing oxygen from the steam and the hydrogen collected. The chemical reaction is represented by the equation:

$$2Fe+3H_2O=Fe_2O_3+6H.$$

To utilize this principle commercially it is necessary to reduce the ferric oxide back again to metallic iron which can be done by passing carbon monoxide over the iron oxide, the carbon monoxide (CO) taking an atom of oxygen from the iron becomes carbon dioxide (CO_2) represented by the following equation:

$$3CO+Fe_2O_3=2Fe+3CO_2.$$

The commercial equipment for production of hydrogen by the iron contact process utilizes the well-known water-gas process for making the carbon monoxide which is needed to reduce the iron from the oxide to pure metallic state. The water-gas generator is filled with coke which is heated to redness by a blast of air for very brief period. When steam is turned on to this red-hot coke, it is decomposed; the hydrogen freed from the oxygen is combined with the carbon of the coke, forming carbon monoxide (CO). The water gas consists principally of hydrogen and carbon monoxide, but must be passed through washers and purifiers to remove dust and particularly sulphurretted hydrogen. Sulphur is removed by passing the gas over trays of iron. The purified water gas, usually referred to as "blue gas," is then stored in a holder, available for use as reducing agent.

After steam has passed over the red-hot iron for a few minutes, the temperature is lowered to such an extent that it no longer decomposes the steam and it is then necessary to raise its heat and at the same time change the ferric oxide to metallic iron by turning the blue gas into the ovens. The period of heating the iron and reducing the oxide requires about twice the amount of time for the hydrogen production phase.

Temperature is a most important factor and must be constantly watched in all phases of the process. In the water-gas generator, if the temperature is too low, carbon dioxide is formed instead of carbon monoxide. In reducing the ferric oxide, if the temperature is not sufficiently high the reduction will be only from the ferric oxide Fe_2O_3 to Fe_3O_4 or at still lower temperature to FeO instead of to the pure metallic Fe.

The reduction ovens are originally filled with hematite (Fe_2O_3) which should be as porous as possible, in order to expose greater surface to the action of the steam and carbon monoxide, and this ore should be free from sulphur compounds and other impurities. It is necessary to replace the ore in the ovens about every six months.

The iron contact process was developed long ago by Coutelle and perfected by Giffard in France, then developed commercially in England by Lane using several retorts for the iron. In Germany it was further developed by A. Messerschmitt, utilizing one large regenerative oven instead of many small retorts. The Messerschmitt regenerative oven is patented in the United States. The patents relate only to the oven and retorts: the steam and iron process is not patented. At least two firms in this country install iron contact plants, which produce 3,500 cubic feet of hydrogen per hour Plants of this size and type are now under construction for the Navy Department at Pensacola, for the Army at Langley field, and for a private firm near Akron, Ohio.

Hydrogen produced by the iron contact process has a purity of at least 98 per cent. The impurities consist principally of nitrogen and carbon dioxide which have no deleterious effect on balloon fabric, nor are these gases inflammable. It is claimed that hydrogen can be produced by this process from 25 cents to 75 cents per 1,000 cubic feet.

ALUMINUM CAUSTIC SODA PROCESS.

During the war between Russia and Japan both armies used field hydrogen generators employing the chemical reaction of alkaline hydrates upon aluminum. Sodium hydrate (NaOH) ordinarily known as caustic soda, is preferred to the potassium hydrate on account of the lower cost of the soda. The chemical reaction taking place is represented by the following equation:

$$6NaOH+2Al=Al_2(ONa)_6+6H$$

The generating apparatus was constructed in two tydes, one of small size installed on vehicles for rapid transportation, and a larger size called "semi-fixed." An iron basket is filled with aluminum scrap, lowered into the solution of caustic soda, the cover being immediately clamped to make it gas tight. The gas passes from the generator to a washing and cooling device which removes the traces of alkaline matter.

In the generator the aluminum is attacked by the soda solution with great energy, the gas coming off rapidly and the liquid heating to the boiling point, but as the proportion of free soda in the solution diminishes, the rate becomes slower. In order to finish the gas production without delay, the generator is charged with caustic soda considerably above the theoretical requirement.

According to the theoretical computation, it is found that to produce 1,000 cubic feet of hydrogen there are required 224 pounds of caustic soda and 51 pounds of aluminum. With caustic soda at 3 cents per pound and aluminum at 50 cents per pound, the cost of the 1,000 cubic feet of hydrogen by this process is $32.22. The actual quantity of materials to be carried will be considerably in excess of 275 pounds and the cost per thousand more than the foregoing computation indicates, on account of the necessity for using an excess of caustic soda and the fact that commercial caustic soda contains impurities, the most common grade containing only 77 per cent sodium hydrate.

The aluminum and alkaline method has the advantage of requiring about 20 per cent less weight of material than the vitriol process and both materials being dry are easily transported without the special care which is necessary for the transportation of sulphuric acid. Furthermore, the hydrogen produced is of greater purity, does not contain volatile hydrocarbons, nor the dangerous gases produced by combinations of hydrogen and arsenic.

United States patent was issued in September, 1901, for a modification of the aluminum-caustic-soda process. The inventor prepared the material by pouring molten caustic soda into a mass of aluminum in the form of powder, filings, or turnings, which was thoroughly mixed before the mass cooled. This mixture of material must be kept in sealed containers to avoid deterioration due to moisture in the atmosphere. When the mixed substance is placed in water the chemical reaction produces sodium aluminate and free hydrogen, probably according to the following equation:

$$2Al+2NaOH+xH_2O=Na_2Al_2O_4+xH_2O+3H_2$$

or

$$2Al+6NaOH+xH_2O=Na_6Al_2O_6+xH_2O+3H_2$$

HYDROLYTHE.

"Hydrolythe" is calcium hydride (CaH_2) manufactured by heating pure metallic calcium in retorts containing hydrogen. To produce hydrogen it is only necessary to drop the granulated hydrolythe into water. Generating equipment similar to the ordinary acetylene gas outfits are suitable. The reason hydrolythe is not more extensively used is on account of its high cost. About 10 years ago the Signal Corps purchased a sufficient quantity to conduct experiments, which confirmed all claims for it, but chemical manufacturers in the United States do not produce it at present. It will be seen from the following chemical equations that only 59 pounds of hydrolythe are required to produce 1,000 cubic feet of hydrogen.

$$CaH_2+H_2O=CaO+4H.$$

At 80 cents per pound for hydrolythe the cost of 1,000 cubic feet of hydrogen by this method would be $47.20.

Pure sodium or lithium dropped in water will produce hydrogen, and it is possible to make hydrates of lithium the same as calcium which will similarly produce hydro-

gen upon contact with water. On account of the light weight of lithium this would be particularly desirable for field hydrogen generation, and experiments are now in progress to determine whether it is practicable to manufacture lithium hydride at reasonable cost.

Dropping pure lithium in water would theoretically require only 40 pounds to produce 1,000 cubic feet of hydrogen

$$2Li+H_2O=Li_2O+2H$$

And of lithium hydride 22½ pounds would produce 1,000 cubic feet hydrogen:

$$2LiH+H_2O=Li_2O+4H$$

About 10 years ago an American manufacturer proposed the use of lead compounds having great affinity for water known as "Hydrone A, B, and C," and experiments were conducted by the Signal Corps. It developed that the chemical reaction upon dropping the substance into an alkaline solution was so violent that the oxygen of the air above the generating tank would burn the hydrogen—the ignition being due to heat of the chemical action. This difficulty was overcome by manufacturing a lower grade which evolved hydrogen slowly. The low grade material was first dropped into the generator until the escaping gas had carried with it all oxygen above the water, then the high-grade substance was fed into the generator. On account of the extreme care that was necessary to avoid explosions with this method and the considerable weight of the hydrone, its further development for field hydrogen generation in the army was discontinued. One pound of hydrone produced only 2.88 cubic feet hydrogen at a cost of 6½ cents per foot.

HYDROGENITE.

The hydrogenite process is a modification of the "silicol" process already described. The chemical substances and reaction are the same as the silicol, but the materials are prepared and used in somewhat different manner. Pulverized ferrosilicon and caustic soda properly proportioned are thoroughly mixed and preserved in hermetically sealed cartridges, each containing 50 kilograms.

The field generators to use these cartridges consist of metal container slightly larger than the cartridge, having a lid which can be clamped down gas tight. After placing the cartridge in the apparatus the top of the can is opened and the mixed powders ignited. Around the inside of the cylindrical burning oven in which the cartridge is placed is a trough to contain a measured quantity of water. The heat produced by the burning of the chemicals quickly converts this water into steam, the silicon, soda, and water combining as in the previously shown equation describing silicol method.

Ignition may be started by a fuse or taper inserted in the powder or by placing on top a small quantity of some easily combustible powder in order to produce sufficient heat in one spot to start the combustion. The hydrogenite burns rapidly and without flame, like tinder; a cartridge of 50 kilograms being consumed in about 10 minutes.

When the mixture is first ignited the air in the chamber and products of combustion are permitted to escape until the pure hydrogen appears. The gas is passed through washing and cooling purifiers before being used.

It is learned that even with the greatest care generators are frequently destroyed by explosions, for which reason the process is not in general use.

HYDROGEN FROM WATER GAS.

A German chemist developed and advocated some years ago the production of hydrogen for aeronautical purposes by first manufacturing water gas in the usual manner, which consists principally of hydrogen and carbon monoxide, passing the water gas over red-hot calcium carbide in the form of powder. The hot calcium carbide decomposes the carbon monoxide, forming lime (CaO) and leaving carbon in the form of crystalline graphite. The inventor claims that minor impurities in the water gas are almost entirely removed in the reaction, producing hydrogen of 99 per cent purity. The report further stated that generating equipment was devised to produce 70,000 cubic feet of hydrogen daily.

Hydrogen may also be separated from water gas or coal gas by the fractional refrigeration process. Hydrogen liquefies under pressure at lower temperature than other common gases, so that from illuminating gas having a considerable percentage of hydrogen it is possible to cool and compress it with liquid-air apparatus, drawing off first all other gases as they liquefy and leaving the hydrogen. This method is not in general use for commercial production for the reason that other methods offer more simple and more economical means of securing hydrogen.

The Electrical Review (vol. 40) reported that M. D'Arsonval passed coal gas previously cooled to minus 80° C. through a Linde liquid-air machine, obtaining 3,500 cubic feet of hydrogen per hour, expending 12 to 15 horsepower. Assuming coal gas to cost \$1 per thousand and containing 50 per cent hydrogen, the cost of material would be about \$2 per thousand cubic feet hydrogen, to which must be added approximately 60 cents per thousand for power, plus cost of expert attendance.

ALUMINUM-POTASSIUM CYANIDE PROCESS.

A French chemist a few years ago advocated the generation of hydrogen for aeronautical purposes by mixing aluminum filings with pulverized bichloride of mercury and potassium cyanide. After these ingredients are thoroughly mixed hydrogen will be produced by adding water. The powder has a density of 1.42 and must be kept in hermetically sealed cans. It is stated that experiments indicated 187 pounds of this material were required to produce 1,000 cubic feet of hydrogen. The chemical reactions which take place should properly be represented by three or four stages, but may be sufficiently explained by the following single equation:

$$6KCN+6H_2O+4Al+3HgCl_2= \\ 2K_3AlO_3+12H+3Hg(CN)_2+2AlCl_3$$

ACETYLENE PROCESS.

In 1901 Mr. H. Houbon, a resident of England, invented and patented a process for making pure hydrogen from acetylene. He compressed the acetylene to 5 atmos-

pheres in a Caillet steel bomb and ignited it by electric spark. The carbon precipitates in the form of fine soot leaving the pure hydrogen. It is stated that the process is without danger, and calcium carbide for producing acetylene is very cheap, but it is not known that this process has ever been perfected for producing hydrogen in large quantities for aeronautical service.

By computation it is found that 180 pounds of calcium carbide are required to produce 1,000 cubic feet of hydrogen by this method.

$$C_2H_2 + \text{Heat} = 2C + 2H$$

IRON AND WATER PROCESS.

Recently an article in a German technical journal described a new method for securing compressed hydrogen of great purity. So far as known it has been employed only in laboratories, but it may be developed later on a commercial scale.

Powdered iron is mixed in water in a vertical steel cylinder, the liquid being subjected to a pressure of 300 atmospheres (5,410 pounds per square inch) and the temperature raised to 350° C. The chemical reaction that takes place is sufficiently explained by the following equation:

$$2Fe + 3H_2O = Fe_2O_3 + 6H$$

from which it is seen that under this great heat and pressure the iron combines with the oxygen from the water, and the hydrogen may be removed at the top of the cylinder already compressed for storage in cylinders. The iron oxide may be easily reduced again to metallic iron, which is facilitated by its porous condition, due to the peculiar manner in which it is oxidized. Hydrogen obtained is said to have 99 per cent purity, which can be further increased to 99.95 per cent by being passed over charcoal. When iron contains sulphur, the sulphur is not attacked, but any carbon content in the iron is converted into carbon monoxide.

SILICO-ACETYLENE PROCESS.

The silicides of clacium, barium, and strontium ($CaSi_2$; $BaSi_2$; $SrSi_2$) are made in the electric furnace similar to the manufacture of calcium carbide. When calcium silicide is added to acidulated water, it is decomposed, leaving silico-acetylene in solution; the calcium oxide is precipitated. The solution is drawn off and evaporated, leaving yellow crystals of silico-acetylene Si_2H_2. When these crystals are added to alkaline solution, such as caustic soda or potash, the silico-acetylene is decomposed, evolving hydrogen. It is reported that 163 pounds of silico-acetylene are required to produce 1,000 cubic feet of hydrogen.

DECARBURATION OF OILS.

About four years ago the Scientific American described equipment developed by the German Army for the generation of hydrogen by the method of decarburizing hydro-carbon oils. The apparatus was designed for installation on two railway cars, the main part of the equipment consisting of two gas producers. To fire up these producers to the proper heat requires from one to two hours.

The producers are filled with coke which is heated to redness by air blast. Crude petroleum or any petroleum distillates are first vaporized and then passed through the producer ovens containing the hot coke, which decomposes the oil. After about 20 minutes the coke has been reduced in temperature so much that it is necessary to heat it again to redness by hot-air blast. This requires only two or three minutes.

The gas produced is passed through water scrubbers and purifiers to remove sulphur. It contains considerable carbon monoxide, which is removed by passing the gas through an oven, the details of which process are not stated. The resultant gas is said to be 98.4 per cent hydrogen, 1.2 per cent nitrogen, and 0.4 per cent carbon monoxide, and to have a specific gravity between 0.087 and 0.092.

BT-2599

German Documents on "Notes of the Balloonist"

Air Service, Washington. D.C.

Ostertag

15 Aug 1920

FOR OFFICIAL USE ONLY

[redacted]

AIR SERVICE INFORMATION CIRCULAR

(LIGHTER-THAN-AIR)

PUBLISHED BY THE CHIEF OF AIR SERVICE, WASHINGTON, D. C.

Vol. II | August 15, 1920 | No. 156

TRANSLATION OF GERMAN DOCUMENTS ON "NOTES OF THE BALLOONIST"

▽

Balloon Notes A. E. F. No. 64

WASHINGTON
GOVERNMENT PRINTING OFFICE
1920

TRANSLATION OF GERMAN DOCUMENTS ON "NOTES OF THE BALLOONIST".

WHAT DOES THE BALLOON SEE?

Look at the panoramic photographs. Each battalion, etc., receives some.

Before all, the balloon sees:

(*a*) The enemy artillery concentrations, the emplacement and extension of barrage fire and enemy C. P. O.'s, and of an enemy gas attack, the enemy zones where the enemy does not fire much, the rockets, the tanks.

(*b*) The flashes of enemy batteries, also the smoke occasioned by their fire. The superstructure of batteries, and the salient points of the terrain in the neighborhood of the batteries, such as isolated trees, hedges, crossroads, etc., facilitate the immediate adjusting.

(*c*) The occupation of enemy camps and P. C.'s by the appearance of smoke.

(*d*) Road traffic, railroad lines with standard and narrow gauge. The moving columns and detachments are specially visible by the dust which they throw up, the railroads (standard and narrow gauge) are visible by a stream of smoke

(*e*) All the illuminating sources, such as sparkling metallic parts or direct light; they furnish excellent departure points for reconnaissance and the laying out.

(*f*) Aviation terrains and balloon emplacements.

(*g*) Friendly troops, batteries, and C. P.'s are kept informed regarding the state of their camouflage.

WHICH ARE THE THINGS A BALLOON DOES NOT SEE?

(*a*) The parts of the terrain where the balloon itself is not seen.

(*b*) The shifting of men in the trenches and in positions, infantry or artillery working at intrenchments, men moving in small number in the open terrain.

HOW MUST TROOPS HELP THE BALLOON?

(*a*) The balloon finds out whether there is any possibility of observing. It can, by experience, judge the view which can be seen from the balloon.

(*b*) At once establish a visual liaison with the infantry balloon, making the visual signals very slowly by separating them clearly; aim carefully at the car of the balloon—a dash, 5 seconds; a point, 2 seconds.

(*c*) Entirely make use of the proper observation conditions of the artillery balloon; often visibility and time rapidly become bad. The batteries must thus rapidly prepare for fire and shorten the ranging by an accelerated precision. The balloon can simultaneously observe for several batteries.

(*d*) The friendly balloons which are detached and go adrift toward the enemy must be brought down by fire as soon as the observer has jumped out. The balloons which would come to land must be kept, owing to the recuperation of its worthy material. Send as soon as possible to the balloon section the matériel (cards, etc.) which might have been thrown and found back. Enemy balloons nor ours must not be brought down when they go adrift toward the interior of our lines.

DUTIES OF THE BALLOONS.

DUTY CONCERNING THE ARTILLERY.

(1) Reconnoiter the enemy batteries and mark their position.

(2) Watch the activity of the enemy batteries fire by means of lights.

(3) Regulate friendly batteries on enemy batteries, trenches, campings, localities, roads, and animated objectives and observe their efficacious fire.

(4) Look out for the important artillery objectives and provoke fire on these objectives by telephone message.

(5) Verify our own barrage regarding the gaps which there might be.

(6) Announce the emplacement and the barrage extension, and the C. P. O. fire.

(7) Combat the fleeting objectives by means of observation batteries.

GENERAL DUTIES.

(1) Observe the railroad and road traffic at the rear of the enemy front.

(2) Help the command, up to the infantry company commander, by photographs and their exploitation.

(3) Maintain liaison with trench posts by visual signals.

(4) Transmit the illuminating signals which have been observed and the requests for barrage and C. P. O. to the concerned elements.

(5) Observe the battle field during action and keep the high command constantly posted regarding the situation.

(6) Foresee the attack sector and the beginning of the attack, from the emplacement and the intensity of fire of the enemy artillery.

7. Designate to the infantry in progression the ways of approach where the enemy does not fire much

(8) Make known to all the troops the hour of the beginning of our own actions by visual signals.

In important combats the balloon will observe the battle field even during night

EFFICIENCY OF THE BALLOONS.

In clear weather, the view of the balloon stretches over 30 kilometers behind the enemy lines. The observation of fire may, in favorable circumstances, be executed on objectives situated up to 10 kilometers in the rear of the

enemy lines; on a very conspicuous objective up to 15 kilometers and more. The immobility of the terrain permits to exactly know the details of the terrain. This advantage is especially appreciable for the observation of fire. The exchange of ideas between the observer and the command or the battery is made directly by telephone and there is perfect and uninterrupted understanding with the observer. The balloon is less independent of the wind and weather than the avion. It is without protection against the attacks of enemy avions and against artillery fire. It is often attacked by avions and artillery. Bad weather requires an extreme tension of the observer's forces to accomplish the missions which are confided to him. Violent winds and electrical discharges expose the worthy matériel and the observer to great dangers. Thus, rational use, avoid all ascensions which are not strictly necessary. Slight damages of the great covering of the balloon may easily cause a temporary disableness.

The troops must take advantage of every opportunity to have balloon officers come to undertake their instruction and detail to the balloon officers from other arms. The ascensions of troop officers in clear weather are indispensable to see the whole layout of the field of action from an observer in a balloon.

(Signed) OSTERTAG.

BT-2600

Regarding Leakage of Hydrogen from Balloons

Air Service, Washington, D.C.

C. De F. Chandler

15 Aug 1920

FOR OFFICIAL USE ONLY

File A 10.12 / 1

AIR SERVICE INFORMATION CIRCULAR

(LIGHTER-THAN-AIR)

PUBLISHED BY THE CHIEF OF AIR SERVICE, WASHINGTON, D. C.

Vol. II | August 15, 1920 | No. 146

MEMO. REGARDING LEAKAGE OF HYDROGEN FROM BALLOONS

Reprint of Balloon Notes A. E. F. No. 39

WASHINGTON

GOVERNMENT PRINTING OFFICE

1920

MEMO. REGARDING LEAKAGE OF HYDROGEN FROM BALLOONS.

JULY 11, 1918.

1. Investigation of leaky balloons by small hydrogen detecters determines that a large proportion of leakage is through the seams instead of through the fabric comprising the panels. Organization commanders and balloon riggers are particularly cautioned to inspect the tape covering the seams, replacing with new tape, carefully and thoroughly cemented, whenever the edges are not firmly attached to the balloon fabric.

2. Whenever a balloon requires an average greater than eight cylinders of hydrogen a day for refilling, the company commander should investigate the cause of excessive leakage. If the seams are found to be properly cemented and covered with tape, next examine the automatic valve adjustment. The wire strand connecting the valve to the top of the ballonet as an automatic safety device should be frequently inspected by an officer, changing the length of the connecting cord so that the valve opens just as the balloon is fully distended and ballonet empty; obviously the valve must not open before nor too late after this critical adjusting point is reached. This is accomplished practically by carefully observing valve and ballonet while fully inflating from cylinders.

3. The average of eight cylinders per day referred to in the preceding paragraph is only a rough approximation. Days when a balloon does not ascend and no extreme of temperature, the evening refilling should never exceed two or three cylinders; whereas if the balloon has made several ascents to maximum altitude on a hot day, the evening refilling of 16 or 17 cylinders would not be considered excessive.

4. Probably the greatest cause of hydrogen wastage is due to lack of appreciation on the part of company personnel regarding the physical laws of the expansion of gases caused by increases in temperature and decrease of atmospheric pressure as the balloon ascends. It has been found that some companies have been adding hydrogen in the morning before ascensions, almost filling the balloon; then as the balloon rises and the air temperature increases, all of the hydrogen added that morning as well as part of that of the refilling the previous evening is lost through the automatic action of the valve. The only condition justifying the addition of gas in the morning is when bad weather conditions prevent the use of the balloon, and at the same time unusual lowering of atmospheric temperature causing the gas in the balloon to condense sufficiently to show large outward folds, tending to increase the diffusion of air through the fabric into the balloon. On warm days the balloon may be quite flabby in early morning, but even if it remains in place on the bed the increase of temperature expands the gas sufficiently to open the valve autmatically, with consequent waste of hydrogen. Officers should remember that a balloon only three-fourths filled early in the morning will be fully distended at 4,000 feet when cloudless days permit the sun to rapidly heat the gas.

5. Practically all the small light holes, which are seen in the fabric of a balloon upon inspecting it from the inside, are caused by the mineral coloring matter in the rubber not being thoroughly mixed and spread evenly. Pure rubber without coloring is transparent, but gas does not escape through it. Every inch of fabric before being made into balloons is thoroughly inspected at balloon factories, each light hole being examined by a magnifying glass to determine whether it is unpigmented rubber or a spot where there is no rubber. In case of the latter the place is marked and a patch put over the hole before the fabric is made into balloon. Small holes may be made in balloons by careless handling and in shipment, all of which should be covered by patches, but the great majority of the so-called pinholes in balloons which are reported to this office are simply the minute spots of transparent rubber, which do not cause leakage of gas.

6. Strict economy in the transportation of supplies from the United States is continually being enjoined by higher authority. The practical application of the instructions on the subject to the balloon service will soon be directed toward an inspection and inventory of equipment in the possession of each company, following that with disciplinary action against C. O. having property in excess of authorized allowances. Organizations holding any surplus are depriving new companies of much-needed equipment.

7. At this period, when American telephone equipment is gradually replacing French equipment for balloon company communication service, it is imperative that ~~all~~ requisitions for dry cells indicate whether for American or French telephones and the sizes of cells desired.

8. Batteries of artillery frequently fire a few rounds at some enemy position which can be observed for the purpose of determining the error of the day caused by changed atmospheric conditions. These registering shots can often be observed more accurately from balloons than from ground stations, and balloon officers should endeavor to serve the artillery in this way to the greatest possible extent. It has been found by experience that cooperation of this nature is most efficient when balloon officers indicate in advance on all battery commanders' maps the prominent landmarks which can be seen clearly from the balloon; then, for the registering shots, the battery commander can select one of those good registering points nearest to his prospective targets.

C. DE F. CHANDLER,
Colonel, A. S. S. C.

BT-2601

The Lift of Hydrogen

Air Service, Washington, D.C.

30 Jan 1921

FOR OFFICIAL USE ONLY
File A 10.1 8/BB 127

AIR SERVICE INFORMATION CIRCULAR

(AEROSTATION)

PUBLISHED BY THE CHIEF OF AIR SERVICE, WASHINGTON, D. C.

Vol. I | January 30, 1921 | No. 27

THE LIFT OF HYDROGEN

(REPRINT FROM BALLOON BULLETIN No. 127)

WASHINGTON
GOVERNMENT PRINTING OFFICE
1921

THE LIFT OF HYDROGEN.

The term "lift" as applied to airships is equivalent to "buoyancy," and, like buoyancy, when applied to water-borne ships it depends on the considerations:

1. The weight of the ship.
2. The weight of supporting medium displaced by the ship.

Here the analogy between water and air-borne craft ceases. For in the case of water-borne ships (other than the submarine) a condition of equilibrium always prevails; if the weight of the ship is increased its displacement is increased, the water line being altered, but a state of equilibrium continues.

The airship, being entirely surrounded by the supporting medium, has no equivalent to the alteration in water-line producing equilibrium. With change in weignt of the displaced supporting medium the airship may possess either positive or negative buoyancy.

While the structural weight of tne ship remains constant, the weight of medium displaced by the ship is subject to considerable variation.

The following affect the buoyancy:

1. The volume of gas in the airship.
2. The purity of the gas.
3. The barometric pressure of the air.
4. The temperature of the air.
5. The amount of water in the air.

Of the five matters affecting the lift of an airship apart from its volume, the purity of the gas is generally to be taken to be the most significant factor, but the combination of temperature and barometric pressure may produce even more important variations.

The maximum purity of hydrogen in an airship does not exceed 98 per cent by volume, while certain chemical considerations necessitate the deflation of the airship at 80 per cent by volume.

Under mean atmospheric conditions, viz, temperature 55° F. and barometer 29.5 inches, the lift of 1,000 cubic feet of hydrogen at 98 per cent purity is 69.7 pounds, while under the same atmospheric conditions at 80 per cent purity it is 56.8 pounds, a variation of 12.9 pounds per 1,000 cubic feet of volume.

Now turning to purely atmospheric effects, 1,000 cubic feet of 98 per cent pure hydrogen at a barometric pressure of 31 inches and at a temperature of 20° F. gives a lift of 78.6 pounds, while an equal volume of gas of the same purity at a barometric pressure of 28 inches and a temperature of 80° F. gives a lift of 63.2 pounds, a variation of 15.4 pounds per 1,000 cubic feet of volume.

Having illustrated the variations in lift due to (1) purity and (2) to atmospheric changes, it is perhaps permissible to state that while the lift of 1,000 cubic feet of hydrogen 98 per cent pure at a temperature of 20° F. and under a barometric pressure of 31 inches is 72.6 pounds, the lift of 1,000 cubic feet of hydrogen 80 per cent pure at a temperature of 30° F. and under a barometric pressure of 26 inches is 51.5 pounds, a variation of 27.1 pounds per 1,000 cubic feet, which represents the extremes of purity and atmospheric conditions which may easily be met with.

Having dealt with the general principles of lift and illustrated its variations by some examples, the question will now be dealt with in detail.

PURITY OF THE GAS.

It is customary to give the chemical composition of the hydrogen in an airship as so many per cent pure. This term requires definition. *By the percentage of purity of hydrogen is meant the percentage of hydrogen contained by volume, assuming the impurity to be of the same density as air.*

Now it will be seen that if the impurity in the hydrogen is air, then, since air in air is without weight, the relative lift of equal volumes of impure hydrogen under the same atmospheric conditions is in the same ratio as their hydrogen contents (by volume).

To sum up: *Lift of unit volume is directly proportional to purity.*

ALTERATION IN LIFT BY BAROMETRIC CHANGE.

One thousand cubic feet of pure hydrogen at 30 inches barometric pressure and a temperature of 40° F. weighs 5.55 pounds; 1,000 cubic feet of dry air under the same atmospheric conditions weighs 80 pounds. Therefore, on the basis lift is the difference between displaced weight and displacing weight—

$$80-5.55 \text{ pounds} = \text{Lift of 1,000 cubic feet of pure hydrogen at 30 inches barometer and } 40° \text{ F.}$$
$$=74.45 \text{ pounds.}$$

Now assume that the temperature remains constant, but that the barometer changes to 31 inches. Then, by the application of Boyle's law, it will be seen that—

$$\frac{80\times 31}{30}-\frac{5.55\times 31}{30}=\text{lift per 1,000 cubic feet of 100 per cent pure hydrogen at 31 inches barometer and } 40° \text{ F.}$$
$$=82.6-5.73,$$
$$=76.93 \text{ pounds.}$$

But the above is an unnecessarily complicated way of arriving at the desired result, for the mathematical expression may be simplified to—

$$\frac{31}{30}(80-5.55)$$
$$=\frac{31}{30}(74.45)$$
$$=76.93 \text{ pounds.}$$

But 74.45 pounds is the lift of 1,000 cubic feet of hydrogen 100 per cent pure at 30 inches barometer and 40° F.

Therefore the rule may be expressed: *Lift of unit volume is directly proportional to barometric pressure.*

ALTERATION IN LIFT BY THERMOMETRIC CHANGE.

By the direct application of Charles's law it can be shown that: *Lift of unit volume is inversely proportional to the absolute temperature.*

To summarize the three rules which have already been stated:

1. Lift of unit volume is directly proportional to *purity.*
2. Lift of unit volume is directly proportional to *barometric pressure.*
3. Lift of unit volume is inversely proportional to *absolute temperature.*

From the above the following formula may be deduced to give the lift of 1,000 cubic feet of hydrogen under any condition of purity, temperature, or barometer:

Lift per 1,000 cubic feet in pounds=

$$\frac{74.45\times\text{per cent purity}\times\text{barometer in inches}\times 500}{100\times 30\times(460+\text{temperature in degrees F.})}$$

$$\frac{12.41\times\text{per cent purity}\times\text{barometer in inches}}{460+\text{temperature in degrees F.}}$$

THE TEMPERATURE OF THE GAS.

In the formula which has been given it has been assumed that the temperature of the gas is the same as the temperature of the air—a condition which generally prevails in the airship shed, but during flight there is frequently a material difference in temperature between the two. This difference arises in two ways:

1. The effect of sun on the gas bag.
2. The effect of a quick descent after flying for a considerable time at a high altitude.

In the first case the sunlight striking the gas-bag fabric causes this to rise above the air temperature, the heat being in course of time transferred to the gas itself. The gas then expands in accordance with Charles's law. Now in rigid airships if the gas bag is not full, or in nonrigid ships if there is air in the ballonets, this expansion will cause a greater volume of air to be displaced and consequently an increase in lift to take place.

For example: At 40° F. and 100 per cent purity 1,000 cubic feet of hydrogen weighs 5.55 pounds, and 1,000 cubic feet of air under the same atmospheric conditions weighs 80 pounds. Hence the lift per 1,000 cubic feet is,

$$80-5.55\text{ pounds}=74.45\text{ pounds.}$$

Now assume that the temperature of the gas rises to 50° F. Its volume instead of being 1,000 cubic feet will be—

$$\frac{1,000\times 510}{5,000}\text{ cubic feet}=1,020\text{ cubic feet.}$$

But its weight is still 5.55 pounds, although the weight of air displaced is not the same; for instead of 1,000 cubic feet being displaced 1,020 cubic feet are displaced, which weigh

$$\frac{80\times 1,020}{1,000}\text{ pounds}=81.6\text{ pounds.}$$

So the lift of the original 1,000 cubic feet of gas becomes

$$81.6-5.55\text{ pounds}=76.05\text{ pounds.}$$

This alteration in lift by difference in temperature of the gas may at first sight appear to be of more academic interest, but in large airships this is certainly not the case. Take the case of a Zeppelin of 1,250,000 cubic feet maximum capacity containing only 1,000,000 cubic feet of hydrogen. The ship is flying in equilibrium when the sun comes out and causes the gas temperature to rise from 40° F. to 50° F. Then, as has already been seen, the lift of the gas is increased 1.6 pounds for every thousand cubic feet of gas in the ship at 40° F., but the volume of the gas was assumed to be 1,000,000 cubic feet; therefore the lift of the ship will be increased—

$$1,000\times 1.6\text{ pounds}=1,500\text{ pounds.}$$

This alteration in lift during flight in large airships is of considerable importance, and it is consequently necessary that the pilot should always be acquainted with the relative temperature of the gas and air, for which purpose electric thermometers are now fitted inside the gas bag, recording in the car.

THE AMOUNT OF WATER IN THE AIR.

Though it may not appear of importance, the humidity of the atmosphere has a certain effect on the lift of hydrogen. The greater the amount of water vapor in the atmosphere the less the weight of unit volume of air, consequently the less the lift of unit volume of hydrogen, for the difference between displaced and displacing weight is less.

This alteration in lift due to humidity is not very material, as it does not generally cause a difference in lift of more than 0.3 pound per 1,000 cubic feet of gas. However, in the case of "lift trials" some adjustment must be made for humidity of the atmosphere. This adjustment can most easily be made by observing the difference in temperature between the wet and dry thermometer and then employing an empirically compiled table which gives the necessary adjustment per 1,000 feet of gas.

THE LIFT OF AIRSHIPS.

So far the lift of hydrogen and the phenomena which affect it have only been dealt with. Now the lift of airships will be considered. Before dealing with this, two terms require definition. One, available lift, the other disposable lift.

Available lift.—Available lift is the total lift of the gas in the airship.

Disposable lift.—Disposable lift is the difference between the available lift and the fixed weight of the airship.

The disposable lift is that buoyance which is available for carrying fuel, oil, crew, and ballast.

As will be seen, both the available lift and the disposable lift will vary with temperature, barometer, humidity, and purity. Consequently a custom has originated in classifying airships on their available lift, assuming the ship to be 100 per cent full, with hydrogen 95 per cent pure, the barometer being 29.5, the thermometer 55° F., and the air dry.

From the formula for lift already given, or by means of the "Scott-Teed" slide rule, it can be calculated that the lift of gas under these conditions is 67.7 pounds per 1,000

cubic feet. Thus the tonnage of existing classes of English airships are

S. S.—

$$\frac{60 \times 67.7}{2,240} \text{ tons} = 1.81 \text{ tons.}$$

C. P.—

$$\frac{185 \times 67.7}{2,240} \text{ tons} = 5.59 \text{ tons.}$$

N. S.—

$$\frac{360 \times 67.7}{2,240} \text{ tons} = 10.88 \text{ tons.}$$

In building airships their disposable lift under the conditions of purity, humidity, barometer, and temperature already mentioned is generally specified, but when the disposable lift is taken practically it is improbable that all, if any, of the specified conditions exist; consequently the practically obtained figure must be converted by simple mathematics to what it would have been had the conditions of the specification prevailed.

To convert disposable lift from one set of conditions to another the following must be known:

1. Disposable lift on the occasion of the trial.
2. Temperature on the occasion of the trial.
3. Purity of gas on the occasion of the trial.
4. Barometer on the occasion of the trial.
5. Humidity of the air on the occasion of the trial.
6. Volume of the gas or fixed weight of ship on the occasion of the trial.

To take an example:

Let it be assumed that by practical trial 9 tons was found to be the disposable lift of a million cubic foot airship, 100 per cent full of hydrogen 98 per cent pure, when the barometer was 30 inches, the temperature 40° F., and the humidity of the atmosphere negligible. It is required to know what would be the disposable lift under the generally specified conditions—namely, 100 per cent full of hydrogen 95 per cent pure, when the barometer is 29.5 inches, the temperature 55° F., and the humidity negligible.

The first thing to be done is to determine the total lift on the occasion of the practical trial.

By means of the lift formula already given, or by means of the "Scott-Teed" slide rule, determine the lift per 1,000 cubic feet of gas on the occasion of the trial. This will be found to be 73 pounds per 1,000 cubic feet.

Now the volume of the ship is known to be 1,000,000 cubic feet. Therefore—

$$\frac{73 \times 1,000}{2,240} \text{ tons is the available lift,}$$
$$= 32.59 \text{ tons.}$$

Now the disposable lift of the ship was found by trial to be 9 tons. Therefore—

$32.59 - 9$ tons is the weight of the ship.
$= 23.59$ tons.

Now by means of formula or slide rule determine the lift per 1,000 cubic feet of hydrogen under the conditions of the specification. This will be found to be 67.7 pounds. Therefore under the conditions of the specification—

$$\frac{67.7 \times 1,000}{2,240} \text{ tons in the available lift.}$$
$$= 30.22 \text{ tons.}$$

But the fixed weight of the ship was found to be 23.59 tons. Therefore—

$30.22 - 23.59$ tons is the disposable lift under specified conditions.
$= 6.63$ tons.

IF THE FIXED WEIGHT IS KNOWN BUT NOT THE VOLUME.

In the example which was taken the volume of the ship was known but not its fixed weight. Now let it be assumed that the weight was known but not the volume. Under these circumstances, if in other respects the same problem was to be solved, the procedure would be:

Determine the lift per 1,000 cubic feet on the occasion and circumstances of the trial. This would be 73 pounds per 1,000 cubic feet.

Now the weight of the ship was known to be 23.59 tons. Therefore—

$23.59 + 9$ tons is the available lift of the ship.
$= 32.59$ tons.

Therefore—

$$\frac{32.59 \times 2,240}{73} \text{ thousand cubic feet is the volume of the ship,}$$
$= 1,000$ thousand cubic feet,
$= 1,000,000$ cubic feet.

IF NEITHER VOLUME NOR FIXED WEIGHT ARE KNOWN.

Occasion may arise when it is desired to know the disposable lift of an airship when the conditions of the specifications do not exist and neither the volume nor the weight of the ship is known.

Let it be assumed that on the occasion of the practical trial the disposable lift was found to be 9 tons when the ship was 100 per cent full of gas of 96 per cent purity and the barometer was 29.8 inches and the temperature 30° F.

Determine the lift of 1,000 cubic feet of hydrogen under these circumstances by formula or rule. It will be found to be 72.5 pounds.

When this has been done, it is necessary to wait until some of the conditions have altered. Assume on a later occasion that the ship is 100 per cent full with hydrogen 95 per cent pure, when the barometer is 28.5 inches and the temperature 60° F. Take the disposable lift, which for purposes of argument will be assumed to be 5 tons.

Then work out the lift per 1,000 cubic feet of hydrogen under the conditions prevailing.

This will be found to be 64.7 pounds per 1,000 cubic feet.

Between the first and the second trial the disposable lift has altered from 9 tons to 5 tons, and the lift per 1,000 cubic feet from 72.5 to 64.7 pounds.

Now the difference per 1,000 cubic feet in lift on the two occasions is:

$72.5 - 64.7$ pounds $= 7.8$ pounds.

The difference in disposable lift—

$9 - 5$ tons $= 4$ tons $= 8,960$ pounds.

Therefore since the fixed weight of the ship has remained constant—

$$\frac{8,960}{7.0} \text{ is the volume of the ship in thousands of cubic feet,}$$
$= 1,148.7$ thousand cubic feet.
$= 1,148,700$ cubic feet.

The volume being now determined, from the methods already described, it is possible to calculate the disposable lift under any conditions whatever.

To summarize, the following are necessary for the conversion of disposable lift:

UNDER CONDITIONS OF LIFT TRIAL.

Available lift 100 per cent full—disposable lift found=fixed weight.

UNDER CONDITIONS TO WHICH DISPOSABLE LIFT IS TO BE CONVERTED.

Available lift 100 per cent full—fixed weight=disposable lift.

NOTE.—Since this memorandum was written, very accurate determinations of the relative weights of hydrogen and dry air have been made by the British National Physical Laboratory, with the result that the lift of 1,000 cubic feet of hydrogen at 30 inches barometric pressure and at a temperature of 40° F. has been found to be 74.05 pounds. Consequently the lift formula should be:

Lift per 1.000 cubic feet=

$$\frac{12.34 \times \text{per cent purity} \times \text{barometer in inches}}{460 + \text{temperature in degrees F.}}$$

The Scott-Teed lift slide rule has been altered in accordance with this determination.

BT-2602

Electrification of Observation Balloons

Air Service, Washington, D.C.

30 Mar 1921

FOR OFFICIAL USE ONLY
File D 52.81/49

AIR SERVICE INFORMATION CIRCULAR

(AEROSTATION)

PUBLISHED BY THE CHIEF OF AIR SERVICE, WASHINGTON, D. C.

Vol. I | March 30, 1921 | No. 38

ELECTRIFICATION OF OBSERVATION BALLOONS

▽

DESCRIPTION AND METHOD OF APPLICATION

WASHINGTON
GOVERNMENT PRINTING OFFICE
1921

ELECTRIFICATION OF OBSERVATION BALLOONS.

DESCRIPTION AND METHOD OF APPLICATION.

INTRODUCTION.

An observation balloon when aloft has the property of collecting charges of static electricity upon its surface, which, because of the fabric being nonconducting will not flow to the ground nor equalize itself upon the surface of the envelope. It therefore frequently happens that two adjacent areas are charged to different potentials and when the pressure becomes great enough it will break down the intervening resistance discharging in the form of a spark. These sparks not only burn the fabric but may even cause an explosion if the proper mixture of hydrogen and air be present.

There is another danger to observation balloons. The earthed cable carrying the same potential as the ground extends far above the ground itself and terminates a short distance from the basket. Should a cloud be encountered with a static charge not yet sufficiently strong to leap to the earth in the form of lightning but yet strong enough to leap to the end of the cable which is considerably nearer, a flash will take place between the cloud and the upper end of the balloon cable. This would in all probability wreck the balloon. Such dangers as these are to be reduced to a minimum by the proper electrification of captive balloons. With that end in view five major principles have been worked out which may be summarized as follows:

1. Good electrical connection between the envelope and the earthed cable.
2. Discharger system connected thereto.
3. The bonding of all projecting metal fittings and their connection to the earthing system.
4. Exclusion of moisture from the interior of the envelope.
5. Effective grounding of balloon cable.

In considering the application of the above principles it should be borne in mind that the vital question of reducing weight to a minimum will seriously conflict with the most efficient arrangement judged from the electrical viewpoint alone. Therefore it has been considered necessary to further modify the plan of electrification as outlined by the Advisory Committee of Aeronautics in their report of February, 1919.

1. GOOD ELECTRICAL CONNECTION BETWEEN ENVELOPE AND EARTHED CABLE.

The envelope should be equipped with a single band of braided copper cable running from the valve to the discharger and from the valve to the upper end of the metallic V. The braid recommended for this purpose is composed of 832 strands of No. 36 wire (B. & S.) woven together to form a flat braided cable 1 inch in width.

The current-carrying capacity of the braid is about half that of the earthed balloon cable but is considered ample for all practical purposes. To equip a balloon with a braid whose current-carrying capacity is equal to that of the cable would necessitate the addition of an excess amount of weight. A conductor of such capacity is unnecessary, as a current in excess of 50 amperes flowing in the cable would never occur except during a lightning flash in which case the balloon would undoubtedly be injured. The purpose of electrifying these balloons is not to provide a path for lightning discharges but rather to prevent so far as possible such a discharge taking place by continually draining off the static envelope charge and the charge in the surrounding atmosphere.

The braided conductor is sewed securely to strips of 2-inch tape, which in turn are cemented to the envelope. The stitching should be of zigzag or wave form extending the width of the braid so as to allow for a reasonable amount of stretching. At the discharger end of the braid 10 inches should be left unsewed to allow for connecting to the discharger.

2. THE DISCHARGER.

The discharger consists of a leather cone 12 inches in height with one-fourth-inch edging at the base. The radius of the base should be 6 inches. The discharger end of the braid should be secured to the cone so as to allow at least 2 inches to project through the apex. The braid thus exposed should be raveled so that each separate wire will stand out like bristles of a brush. The lower end of the braid terminates in a standard connector. The cone is to be placed on the highest point on the envelope. A fabric-chafing patch should be cemented at this place to prevent the leather from chafing the envelope. The cone will have two holes punched near the apex in such a manner as to allow for necessary ventilation and at the same time to be waterproof. The cone itself is secured to the envelope by three straps placed at equal distances about the circumference of the base and fastening by hand stitching to corresponding straps on the collar of the cone. When the balloon is to be packed the cone can be easily removed, thereby doing away with all rigid parts which might damage the fabric. To place in operation again it is only necessary to bolt the connectors together and sew the cone straps to the chafing-patch straps. The reason for sewing the cone straps is to do away with small auxiliary metal parts not grounded.

3. THE BONDING OF ALL PROJECTING METAL FITTINGS AND THEIR CONNECTION TO THE EARTHING SYSTEM.

Extreme care should be exercised in making all connections strong both electrically and mechanically. Wherever possible joints should be soldered, and where this is im-

practical a strong clamp connector should be used, first thoroughly cleaning the surfaces, which are to be brought into contact. The braid from the valve should be clamped to the upper end of the metallic V just below the ring to which the rigging is attached. Good electrical connection between the metallic V and the earthed cable is also essential. All other metal parts should be effectively bonded together and connected to the earthed cable.

4. EXCLUSION OF MOISTURE FROM THE INTERIOR OF THE ENVELOPE.

It is probably impossible to exclude moisture altogether from the interior of the envelope, but every precaution should be taken to keep the inner surface dry. The most probable source of moisture is rain entering through the valve. This it is believed will be prevented by the valve cover clamped to the valve ring.

5. EFFECTIVE GROUNDING OF BALLOON CABLE.

Unless the balloon is efficiently and effectively grounded all the precautions described above are not only worthless, but become a source of danger to the balloon. It is therefore necessary to have a means of grounding the cable under any conditions which may exist with as little trouble as possible. The device for this purpose consists of a round 40-inch steel stake, heavily galvanized, diameter 1 inch, tapering the last 6 inches to a point. The head should be equipped with a 14-inch bar or handle and a 2-inch boss, so that it may be driven into the ground with a mallet. To the stake, just below the handle, is bolted 30 feet of phosphor-bronze stranded cable approximately equivalent to size No. 1/0 B. & S. gauge; the other end is securely fastened to the winch. When not in use the flexibility of the phosphor-bronze cable allows it to be coiled up into a very small space. Before an ascent is made the stake should be driven deep in the ground at the point of greatest moisture. If the ground is dry, pour water around the stake. The 14-inch handle allows the stake to be withdrawn with comparative ease. In case the cable attached to the stake breaks or needs renewing and there is no phosphor-bronze cable at hand, a length of balloon cable may be substituted or the equivalent size of copper cable, extreme care being taken with the connections.

THEORY OF OPERATION.

The action of a discharger applied to a balloon as described in the foregoing paragraphs is similar to that of a lightning rod attached to a building. The points on the cone discharge the approaching cloud before a sufficiently high potential has accumulated to break down the intervening air resistance. In this way the pressure between the cloud and the points is gradually neutralized or rather equalized and no flash can take place. A similar phenomenon may be observed in the laboratory: An electroscope can be easily discharged by a pointed conductor held near it while a blunt conductor at the same distance will have no effect.

It can not be guaranteed that this system of electrification will prevent flashes from taking place any more than it can be guaranteed that lightning rods on a building will prevent its being struck. If a cloud approaches faster than the points are able to discharge it, a flash will undoubtedly occur. However, it is known by experience that a building properly protected from lightning is a better risk than a building under the same conditions without such equipment and the same may be said of balloons.

The discharger should equalize the charge accumulated on the surface of the envelope in the same manner as that on a cloud. It is therefore unnecessary to encumber a balloon with a complicated net work of braid. The addition of other dischargers would no doubt improve the operation of the system, but the added efficiency would not compensate for the increase in weight. A perfectly conducting fabric is the ideal solution to the entire problem, but so far none has been developed.

DETAILS RELATIVE TO THE MATERIALS.

1. The *electrification arrangement* consists of:
   - (*a*) Discharge.
   - (*b*) Discharge attachment patch.
   - (*c*) One inch flat copper-braid conductor.
   - (*d*) Connections from copper conductors for balloon cable.
   - (*e*) Phosphor-bronze stranded ground cable.
   - (*f*) Ground stake.
   - (*g*) Cable clamp for ground stake.
   - (*h*) Connection to the winch frame.
   - (*i*) Valve apron and connection to the valve.

2. *Statement of estimated weights.*

No. detail	Part.	Number required	Unit weight.	Total weight
			Pounds	*Pounds*
1256-2.	Discharge tip	1	0.24	0.24
1254-1	Discharge cone with straps	1	1.80	1.80
1255	Discharger patch, complete	1	.80	.80
Std	Cable, braided (60 feet), complete	1	4.48	4.48
1253-2	Tape for cable	1	.69	.69
1256-3	Jumper connection at metallic V	1	.17	.17
1256-3	Connections from copper conductors to balloon cable	3	.077	.23
Std	Bolts and nuts (¼ by ¾ inch)	12	.033	.396
1256-5	Ground cable connector at winch	1	.06	.06
Std	Ground cable, complete (30 feet)	1	7.65	7.65
1256-1-4	Ground stake, complete	1	11.00	11.00
1257	Valve apron	1	3.00	3.00
	Total weight			30.28

3. *Discharger.*—The tip of the discharger is made of No. 16 B. & S. gauge copper tube, 1 inch in diameter, expanded to form the apex of a cone. The support for this tip is made of leather, waterproofed along the seam and shaped to form the body of a cone near the bottom of which is stitched three strap fasteners. Means are provided for securing a braided copper cable to the discharger tip with a brass or copper bolt.

4. *Discharger attachment patch* is made of two layers of ballonet fabric; the outer patch to be notched on the outer edge to prevent this edge from curling. There are to be further patches taped over the ends of the several strap fasteners. The straps from the cone and the straps on the patch are to be fitted and sewn together on assembly.

5. *Braided conductor* consists of 60 feet of 832 strands of No. 36 B. & S. copper wire woven together to form a flat braid 1 inch in width (Std. Belden braid), and sewn to strips of 2-inch tape made of ballonet fabric which in turn are to be cemented to the envelope. The stitching should be of a zigzag or wavo form to allow a certain necessary amount of stretching after assembly. The one end of this conductor is frayed to form a wire brush or discharger, near which end the braid is to be spot-soldered and drilled to take a ¼-inch brass bolt in order to rigidly secure this conductor to the discharger tip. The

other end of the conductor is to be bolted with ¼-inch bolt to a special clamp on the steel balloon cable leading down to the metallic V.

6. *Connections to balloon cable* consist of several special steel clamps of No. 16 gauge cold-rolled steel, to which are bolted the standard copper terminals of the braided conductor on the balloon and jumper connection at the junction piece. A copper lining of No. 16 B. & S. copper is to be inserted in each.

7. The *jumper connection* consists of a short length of the flat braided conductor, heretofore specified, soldered into No. 16 B. & S. gauge copper terminals as specified in paragraph (16). This connection should be of sufficient length to short circuit the junction piece.

8. *Ground cable* consists of 30 feet of five-sixteenth-inch diameter phosphor-bronze stranded cable, each end of which is to be fitted and soldered into a standard 16 B. & S. copper terminal of the spade type, with ¼-inch opening.

9. The *ground stake* consists of a bar of 1-inch diameter cold-rolled steel heavily galvanized of sufficient length to penetrate the ground to 36 inches. This stake is upset to form a driving head and a 12-inch handle is welded thereto, to permit withdrawal. A connection clamp made of No. 14 B. & S. hard-drawn copper strip is brazed to a scraped portion of this stake immediately beneath the handle.

10. The *connection to winch frame* consists of a clip made of No. 14 gauge copper to which is bolted one end of the ground cable. This clip is to be securely brazed and bolted to the winch frame.

11. *Valve cover* consists of a spun cover and collar of No. 20 United States gauge aluminum, of at least 10 inches clear height inside and designed to readily fit the type R balloon valve as specified in United States Air Service specifications Nos. 2114 and 2118. This valve apron is so designed as to prevent water from entering the balloon through the valve, and shall be further provided with a weather-proof handhole to permit valve adjustment when in place. The valve and valve apron are grounded to the main braided conductor by a short length of braided cable (hereinbefore specified) soldered at the junction with the main cable, and terminating at the valve apron in a standard No. 16 B. & S. gauge copper terminal. This copper terminal is secured to the nearest valve apron stud with a wing nut.

12. All connections between copper and copper unless soldered only, are to be made with a brass bolt and nut. All connections between copper and steel, or steel and steel, are to be made with a steel bolt and nut. Wing nuts are used at points where quick disconnection is necessary, while standard hexagon nuts are used at all other points.

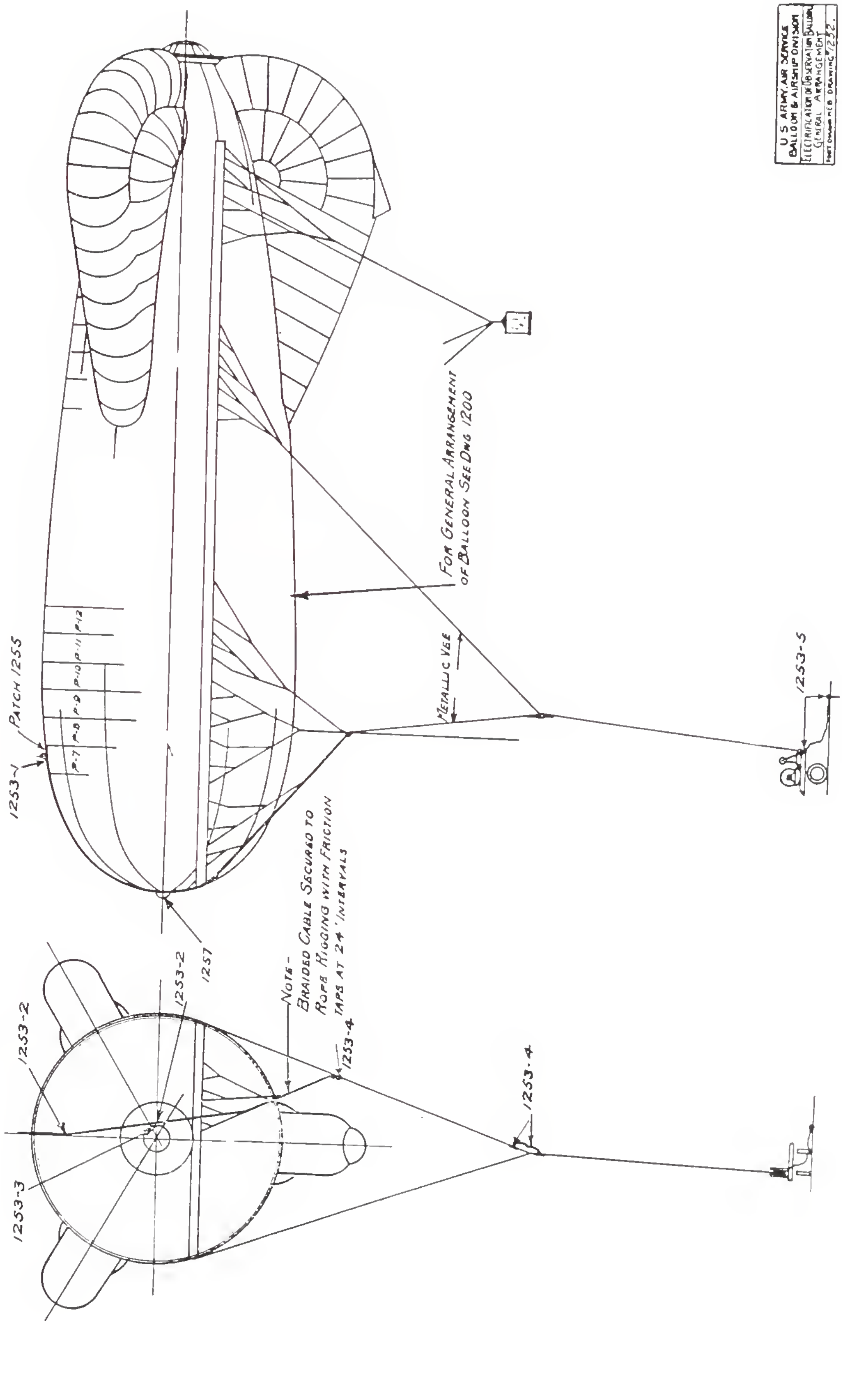
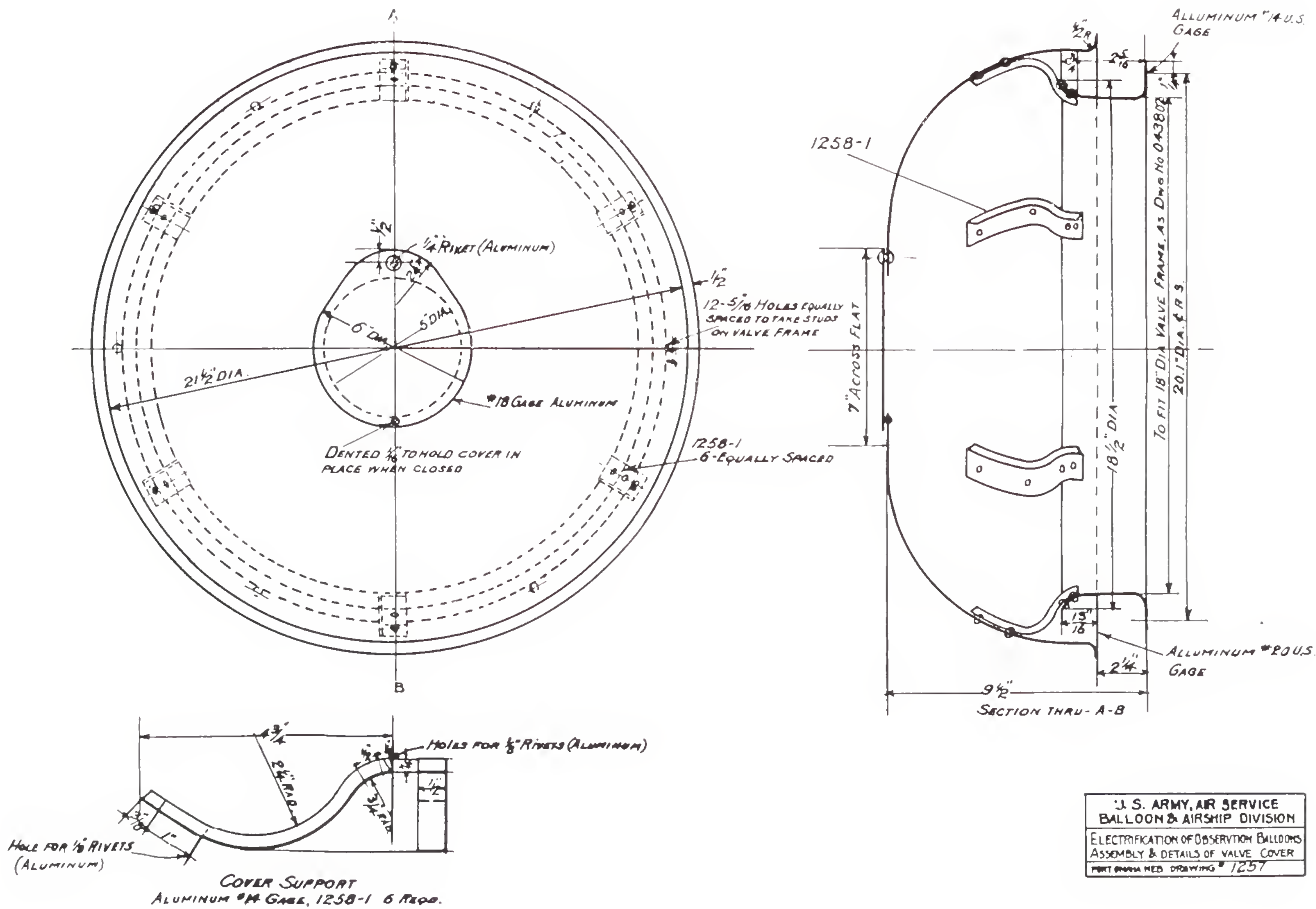

U S ARMY AIR SERVICE
BALLOON & AIRSHIP DIVISION
ELECTRIFICATION OF OBSERVATION BALLOON
GENERAL ARRANGEMENT
FOR GENERAL ARRANGEMENT OF BALLOON SEE DWG 1200
METALLIC VEE
PATCH 1255
1253-1
P-7
P-8
P-9
P-10
P-11
P-12
1253-5
1257
NOTE - BRAIDED CABLE SECURED TO ROPE RIGGING WITH FRICTION TAPE AT 24" INTERVALS
1253-2
1253-2
1253-3
1253-4
1253-4

Fig. 1



A
B
1/2"
1/4" Rivet (Aluminum)
6" Dia.
5" Dia.
21 1/2" Dia.
#18 Gage Aluminum
Dented 1/16" to hold cover in place when closed
1 1/2"
12-5/16 Holes equally spaced to take studs on valve frame
1258-1
6-Equally Spaced
1258-1
7" Across Flat
18 1/2" Dia
To fit 18" Dia valve frame, as Dwg No 043802
20.1" Dia. & R. S.
Alluminum #14 U.S. Gage
Alluminum #20 U.S. Gage
2 5/16
13/16"
2 1/4"
9 1/2"
Section thru - A-B
Holes for 1/8" Rivets (Aluminum)
Hole for 1/8" Rivets (Aluminum)
2 1/4" Rad.
3/4" Rad.
1"
Cover Support
Aluminum #14 Gage, 1258-1 6 Reqd.
U.S. Army, Air Service
Balloon & Airship Division
Electrification of Observation Balloons
Assembly & Details of Valve Cover
Fort Omaha Neb Drawing # 1257

Fig. 2.

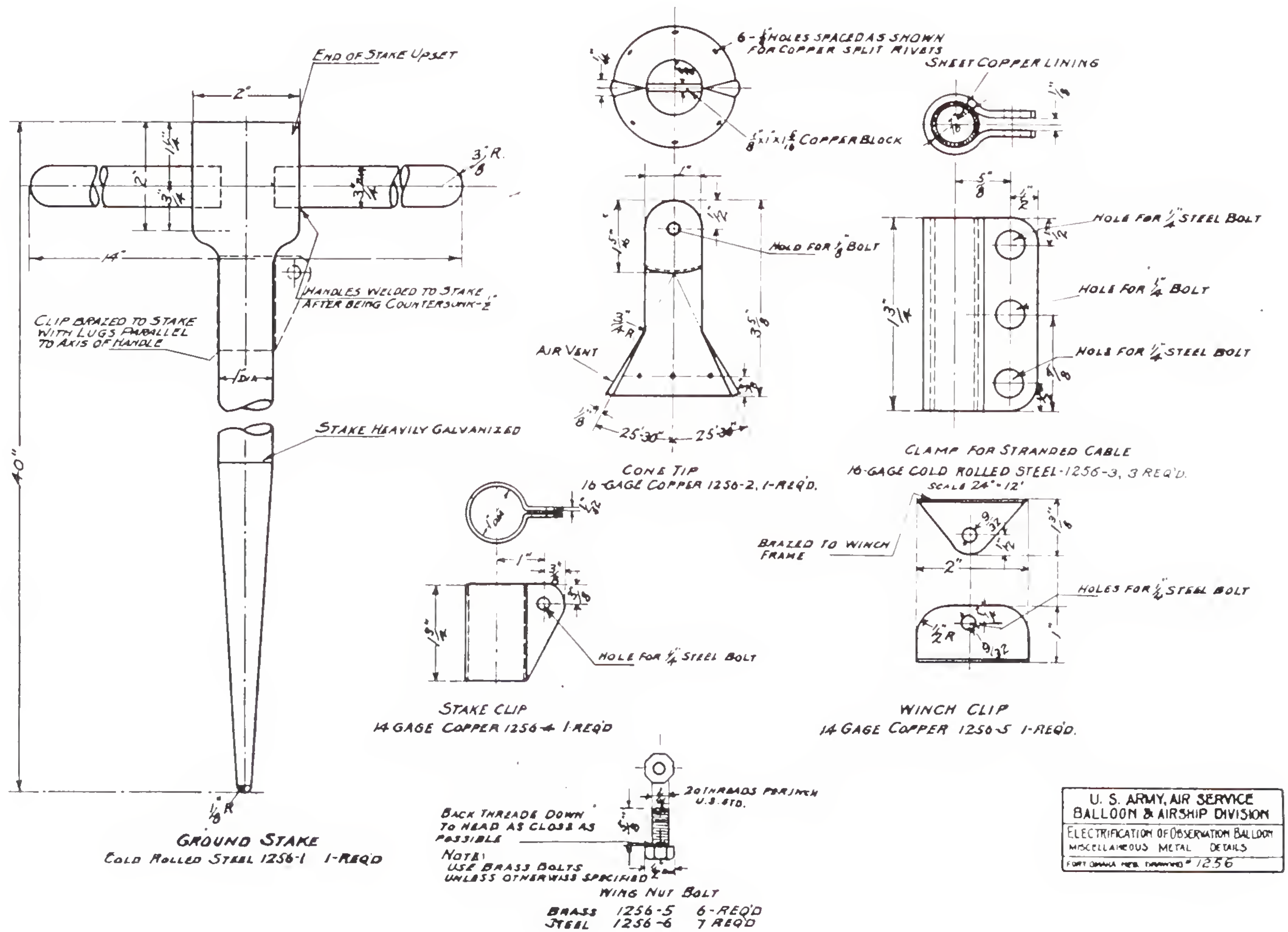
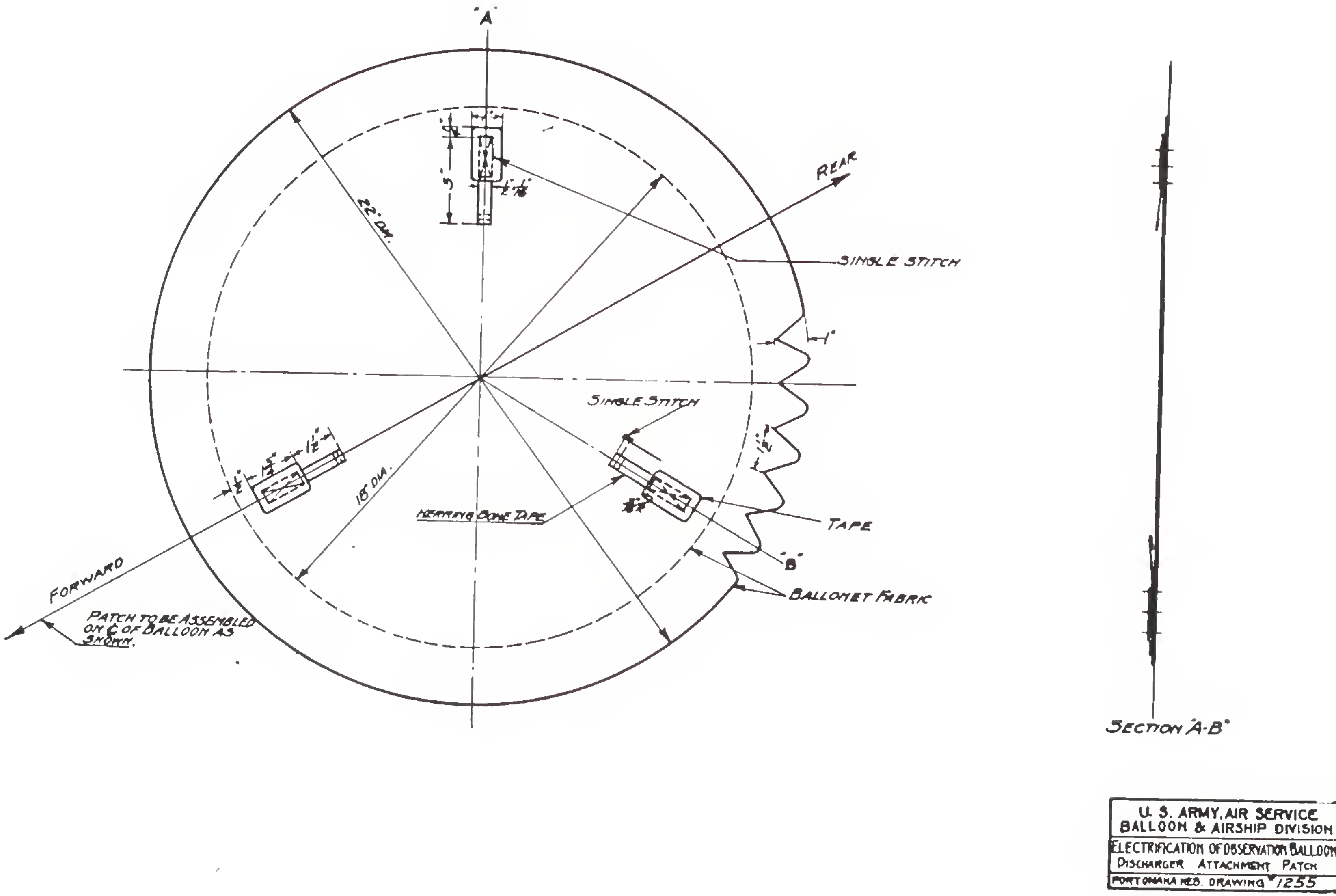

END OF STAKE UPSET
HANDLES WELDED TO STAKE AFTER BEING COUNTERSUNK-$\frac{1}{2}$"
CLIP BRAZED TO STAKE WITH LUGS PARALLEL TO AXIS OF HANDLE
STAKE HEAVILY GALVANIZED
GROUND STAKE
COLD ROLLED STEEL 1256-1 1-REQ'D
6-$\frac{1}{8}$" HOLES SPACED AS SHOWN FOR COPPER SPLIT RIVETS
$\frac{1}{8}$"x1x1$\frac{5}{16}$ COPPER BLOCK
HOLE FOR $\frac{1}{8}$" BOLT
AIR VENT
CONE TIP
16-GAGE COPPER 1256-2, 1-REQ'D.
SHEET COPPER LINING
HOLE FOR $\frac{1}{4}$" STEEL BOLT
HOLE FOR $\frac{1}{4}$" BOLT
HOLE FOR $\frac{1}{4}$" STEEL BOLT
CLAMP FOR STRANDED CABLE
16-GAGE COLD ROLLED STEEL-1256-3, 3 REQ'D.
SCALE 24"=12'
BRAZED TO WINCH FRAME
HOLES FOR $\frac{1}{4}$" STEEL BOLT
HOLE FOR $\frac{1}{4}$" STEEL BOLT
STAKE CLIP
14 GAGE COPPER 1256-4 1-REQ'D
WINCH CLIP
14 GAGE COPPER 1256-5 1-REQ'D.
20 THREADS PER INCH U.S. STD.
BACK THREADS DOWN TO HEAD AS CLOSE AS POSSIBLE
NOTE:
USE BRASS BOLTS UNLESS OTHERWISE SPECIFIED
WING NUT BOLT
BRASS 1256-5 6-REQ'D
STEEL 1256-6 7 REQ'D
U. S. ARMY, AIR SERVICE
BALLOON & AIRSHIP DIVISION
ELECTRIFICATION OF OBSERVATION BALLOON
MISCELLANEOUS METAL DETAILS
FORT OMAHA NEB. DRAWING # 1256

FIG. 3


"A"
22" DIA.
3"
REAR
SINGLE STITCH
1"
SINGLE STITCH
FORWARD
PATCH TO BE ASSEMBLED ON ℄ OF BALLOON AS SHOWN.
18" DIA.
HERRING BONE TAPE
TAPE
"B"
BALLOMET FABRIC
SECTION "A-B"
U. S. ARMY, AIR SERVICE
BALLOON & AIRSHIP DIVISION
ELECTRIFICATION OF OBSERVATION BALLOONS
DISCHARGER ATTACHMENT PATCH
PORT OMAHA NEB. DRAWING # 1255

IG. 4.

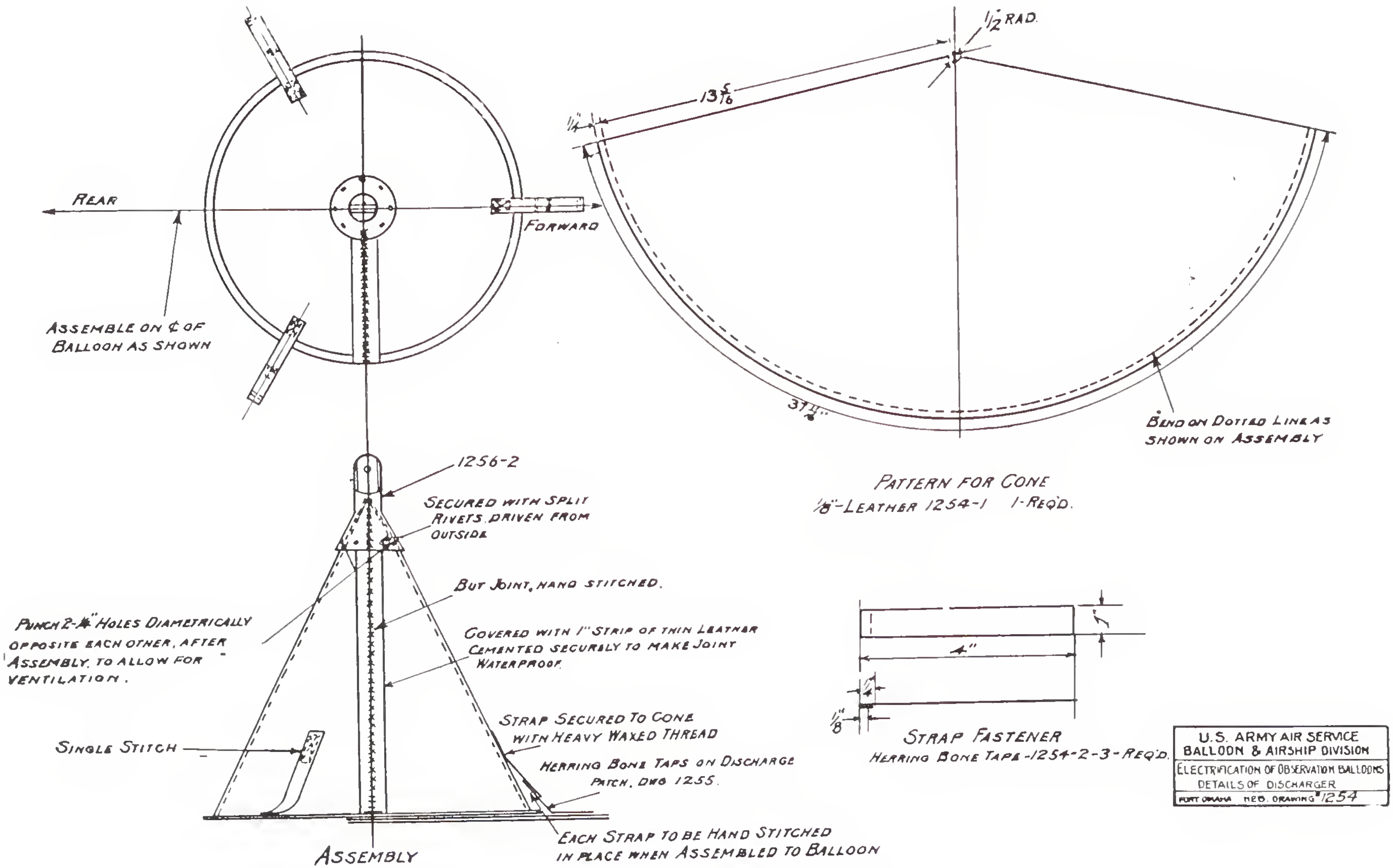

REAR
FORWARD
ASSEMBLE ON ℄ OF
BALLOON AS SHOWN
1½" RAD.
13 5/16
1/4"
37 1/2"
BEND ON DOTTED LINE AS
SHOWN ON ASSEMBLY
PATTERN FOR CONE
1/8"-LEATHER 1254-1 1-REQ'D.
1256-2
SECURED WITH SPLIT
RIVETS DRIVEN FROM
OUTSIDE
BUT JOINT, HAND STITCHED.
PUNCH 2-1/4" HOLES DIAMETRICALLY
OPPOSITE EACH OTHER, AFTER
ASSEMBLY, TO ALLOW FOR
VENTILATION.
COVERED WITH 1" STRIP OF THIN LEATHER
CEMENTED SECURELY TO MAKE JOINT
WATERPROOF.
STRAP SECURED TO CONE
WITH HEAVY WAXED THREAD
HERRING BONE TAPS ON DISCHARGE
PATCH, DWG 1255.
SINGLE STITCH
EACH STRAP TO BE HAND STITCHED
IN PLACE WHEN ASSEMBLED TO BALLOON
ASSEMBLY
4"
1/8"
STRAP FASTENER
HERRING BONE TAPE-1254-2-3-REQ'D.
U.S. ARMY AIR SERVICE
BALLOON & AIRSHIP DIVISION
ELECTRIFICATION OF OBSERVATION BALLOONS
DETAILS OF DISCHARGER
FORT OMAHA NEB. DRAWING # 1254

FIG. 5.

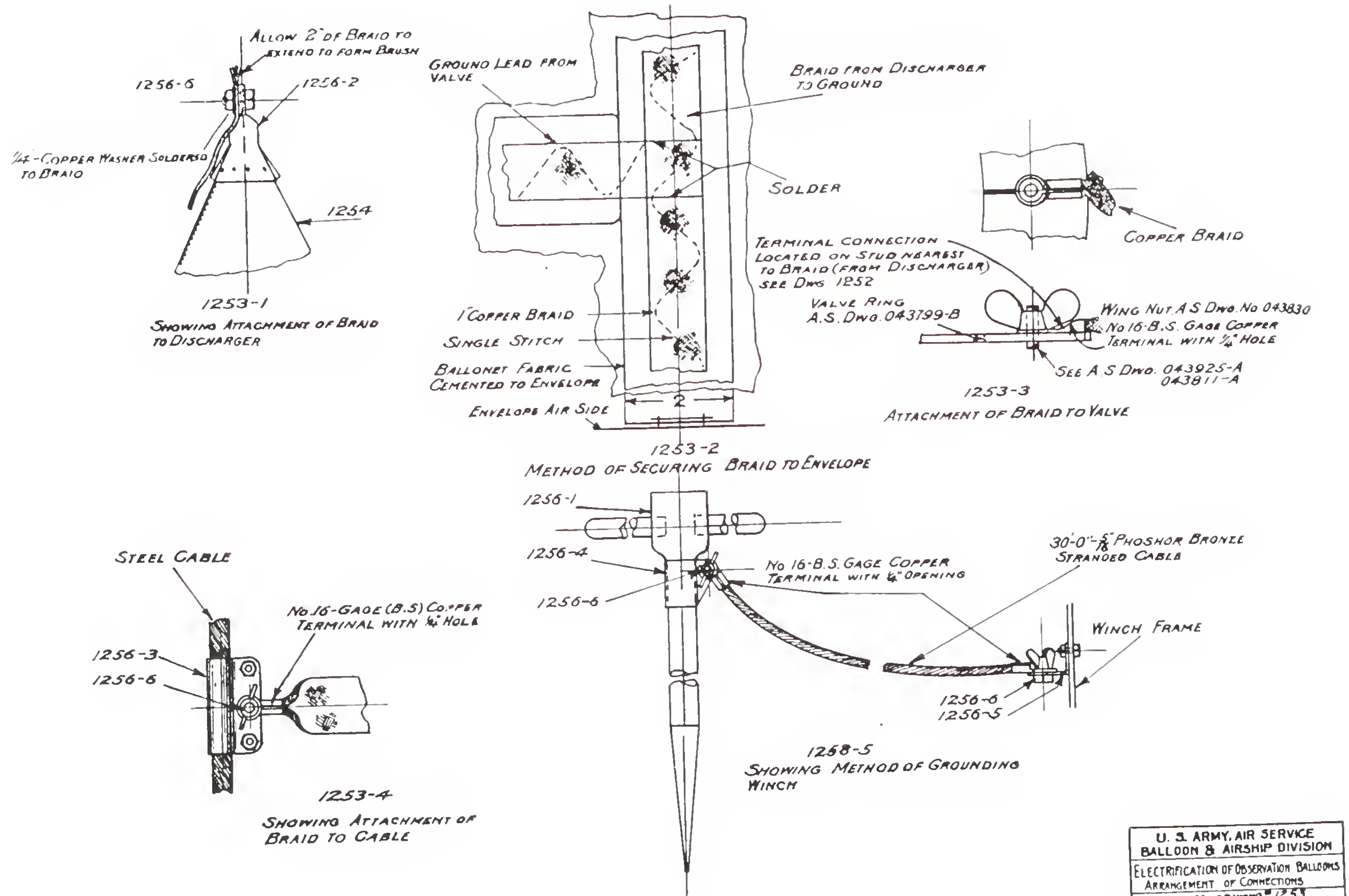

Allow 2" of Braid to extend to form Brush
1256-6
1256-2
¼-Copper Washer Soldered to Braid
1254
1253-1
Showing Attachment of Braid to Discharger
Ground Lead from Valve
Braid from Discharger to Ground
Solder
1" Copper Braid
Single Stitch
Ballonet Fabric Cemented to Envelope
Envelope Air Side
2
1253-2
Method of Securing Braid to Envelope
Copper Braid
Terminal Connection Located on Stud nearest to Braid (from Discharger) see Dwg 1252
Valve Ring A.S. Dwg. 043799-B
Wing Nut A.S Dwg. No 043830
No 16-B.S. Gage Copper Terminal with ¼" Hole
See A.S Dwg. 043925-A 043811-A
1253-3
Attachment of Braid to Valve
1256-1
1256-4
1256-6
No 16-B.S. Gage Copper Terminal with ¼" Opening
30'-0"-5/16" Phoshor Bronze Stranded Cable
Winch Frame
1256-6
1256-5
1258-5
Showing Method of Grounding Winch
Steel Cable
No 16-Gage (B.S) Copper Terminal with ¼" Hole
1256-3
1256-6
1253-4
Showing Attachment of Braid to Cable
U. S. ARMY, AIR SERVICE
BALLOON & AIRSHIP DIVISION
Electrification of Observation Balloons
Arrangement of Connections
Fort Omaha Neb. Drawing # 1253.

Fig. 6.